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Holding Power of Anchor Bolts

Civil Engineering B. S.

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HOLDING POWER
of
ANCHOR BOLTS

by

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

J. M. Alarco

ENTITLED Holding Power of Anchor Bolts.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering.

Ira O. Baker.

HEAD OF DEPARTMENT OF Civil Engineering.

HOLDING POWER OF ANCHOR BOLTS

Anchor bolts as their names indicate are rods set in engineering structures for the purpose of holding or anchoring the structures. Anchor bolts are used in the foot of columns of elevated rail-roads, in bed plates of bridges, in foundations of engines, in bases of cast iron light posts, etc.

Little experimenting has been done on this subject, and an extensive examination of engineering litterature revealed only the following:

1. Mr. Robert Moore,* of St. Louis, with one smooth bolt set ten days in Harris Portland Cement got a resistance of 900 lbs. per sq. in. of surface of contact, and with one threaded bolt obtained a little less.

2- Mr. E. F. Miner§ found, in a series

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* Engineering Record, Vol. 23, p. 209.

§ Engineering Record, Vol. 36, p. 43.

of experiments with lead and sulphur, 900 lbs. per sq. in. for sulphur and about the same for threaded bolts in lead; for plain bolts the average was less than 200 lbs. per sq. in.

3. An experimenter signing himself A.A.S* with cement two weeks old found a resistance of 450 lbs. per sq. in.

4. Mr. E.S. Wheeler§ obtained 500 lbs. per sq. in. for rods set one month in mortar made of one part Portland Cement and two parts limestone screenings.

5. Mr. M.M. Willcox†, Civil Engineering Class '99, University of Illinois, in his Bachelor's Thesis gives an account of a series of experiments made by himself.

Of the above experiments the only ones that were at all extensive are Nos. 4 and 5. In the others only from two to four rods were tried with different kind of cementing material.

Mr. E.S. Wheeler found that the different shapes of cross-section and sizes

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* Engineering News, Vol. 24, p. 53; also Engineering Record, Vol. 22.

§ Report of Chief of Engineers, U.S.A. 1895, Part IV, p. 2907, 2904-41.

† Manuscript in Library of University of Illinois. A brief summary was published in The Technograph, No. 13, 1899-00, p. 38-40.

of the bolts did not affect their resistance.

Mr Willcox's experiments are the most extensive. He finds that sulphur is the best cementing material, and next cement if allowed to set, then lead. His results are as follows:

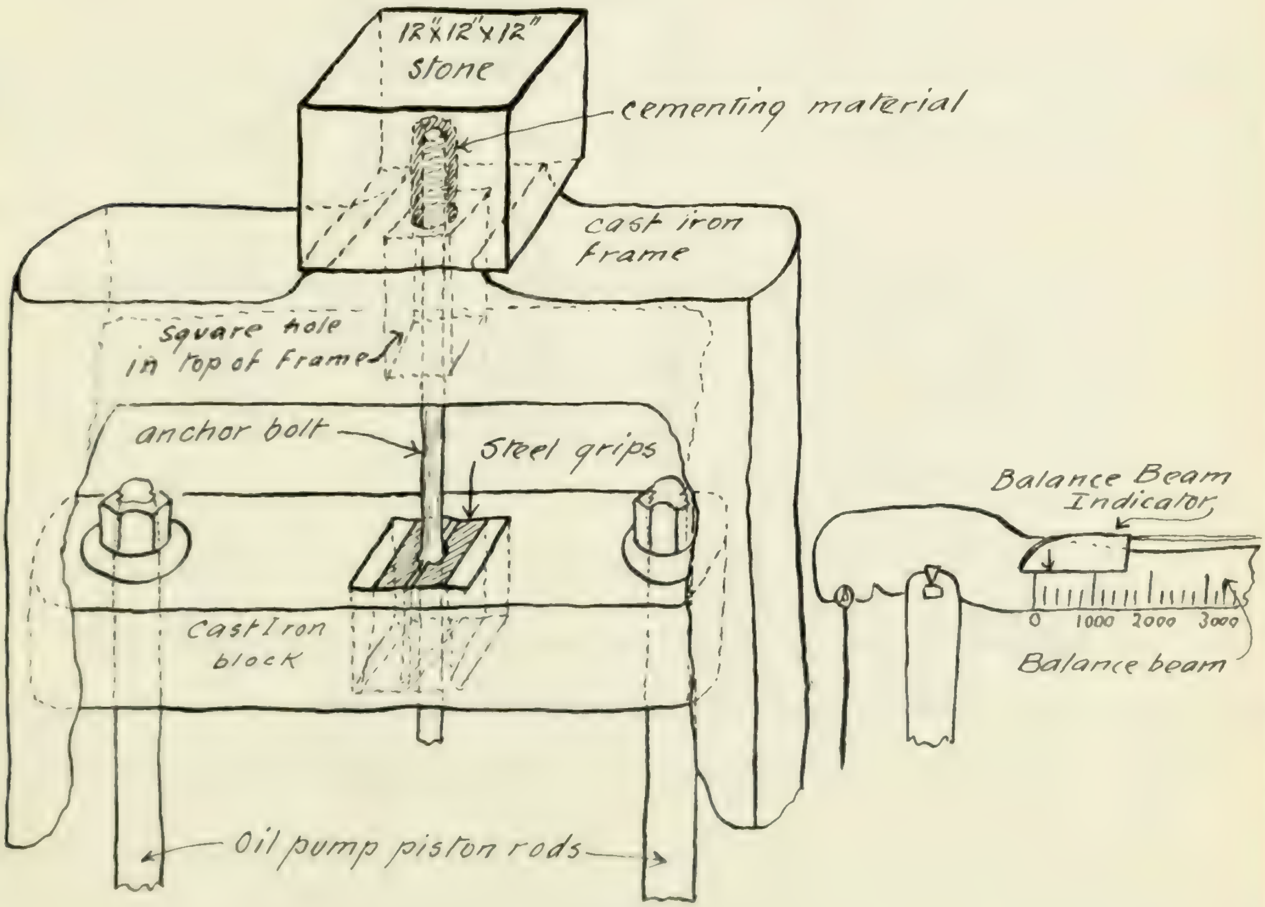
Cement	12	Smooth rods	106	lbs. per sq. in. of bearing surface
"	5	Notched "	336	" " " " " " "
"	4	Threaded "	585	" " " " " " "
Sulphur	1	Smooth "	200	" " " " " " "
"	1	Notched "	328	" " " " " " "
"	7	Threaded "	1647	" " " " " " "
Lead	5	Smooth "	167	" " " " " " "
"	1	Notched "	460	" " " " " " "
"	6	Threaded "	903	" " " " " " "

The purpose of this investigation is to ascertain: (1) The best material to use for anchoring bolts in stone; and (2) The best shape to give to the bolts. The writer tested the following methods of anchoring:

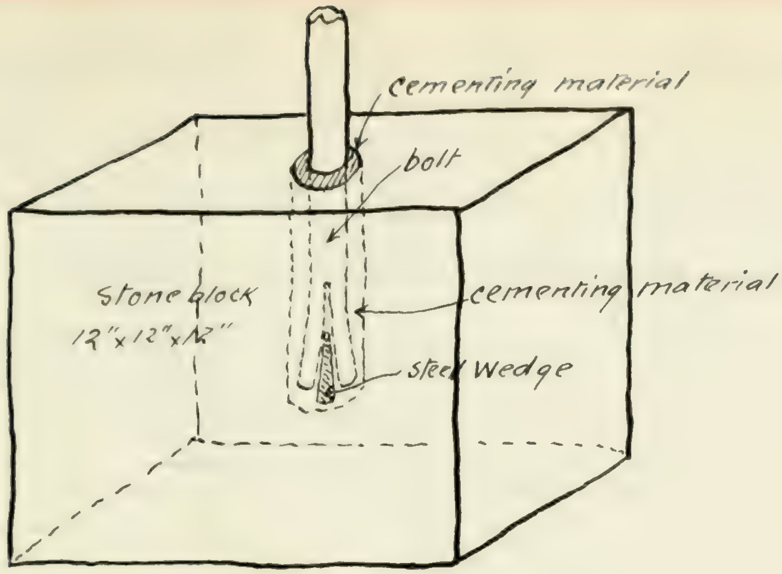
Plain bolts cemented with Portland Cement, lead, and sulphur
Threaded " " " " " " " "
Wedged " " " " " " " "
Wedged " without any cementing material.

The method of procedure was as follows: Blocks of stone 12" in every dimension were procured and holes were drilled in them

from 4" to 12" deep by means of a compressed air drill. The different cementing materials were poured in, and the bolts left to stand from three to fifteen days before proceeding to pull them out. When the time came to do so, the stones were placed on a Riehle testing machine. The sketch shows a relation of the several parts in the testing machine.



The writer also tried the shape of bolt shown in the following sketch using with it cement, lead or sulphur.



Four tests were made in which the bolt was simply wedged in 12" Barea sandstone cubes without any cementing material. The results were as follows:

Exp. No.	Stress	Remarks
1	4000	Stone Split
2	11000	Rod pulled out
3	17000	Stone Split
4	14000	Stone Split

This way of setting bolts is seldom used in practice, some kind of cementing material always being poured around the bolt.

The writer tried to find out by inquiry of practical men the material generally used, but all of the above methods of fixing anchor-bolts are employed, some prefering one and some the

other, with apparently no scientific reason for the choice.

The results of the writer's experiments are shown in the following tables.

TABLE III
Results for Bolts set in Lead

No. of Exp	Dimensions			Kind of Bolt	Stress			
	Diam in inches	Length in inches	Surface of contact in sq. in.		Starting		Ultimate	
					Total	lbs. per sq. in	Total	lbs. per sq. in.
4	1	4	12.56	plain	2400	191	2400	191
12	1	4	12.56	"	2500	199	2500	199
					Mean	195		195
3	$1\frac{1}{8}$	7	24.71	threaded	2000	81	2000	81
5	$1\frac{1}{8}$	7	24.71	"	5000	202	5000	202
7	$1\frac{1}{8}$	7	24.71	"	2000	81	2000	81
8	$1\frac{1}{8}$	6	21.18	"	5000	236	5000	236
10	$1\frac{1}{8}$	7	24.71	"	4000	162	4000	162
					Mean	152		152
1	$1\frac{1}{16}$	4	13.36	wedged	11000	823	17400	1302
2	$1\frac{1}{16}$	3	10.02	"	14000	1397	24800	2475
6	$1\frac{1}{16}$	4	13.36	"	14000	1048	34000	2545
9	$1\frac{1}{16}$	4	13.36	"	15000	1123	25000	1871
11	$1\frac{1}{16}$	4	13.36	"	12000	900	12000	900
					Mean	1078		1819

TABLE II
Results for Bolts Set in Sulphur

No. of Exp.	Dimensions: Diam in inches	Dimensions: Length in inches	Dimensions: Surface of Contact in sq. in.	Kind of Bolt	Stress: Starting: Total	Stress: Starting: lbs. per sq. in	Stress: Ultimate: Total	Stress: Ultimate: lbs. per sq. in.
1	$1\frac{1}{8}$	5	17.65	plain	1500	85	1500	85
5	1	5	15.70	"	1600	101	1600	101
					Mean	93		93
2	$1\frac{1}{8}$	5	17.65	notched	3000	161	3000	161
					Mean	161		161
3	$1\frac{1}{8}$	6	21.18	threaded	3100	146	3100	146
4	$1\frac{1}{8}$	7	24.71	"	2200	89	2200	89
9	$1\frac{1}{8}$	6	21.18	"	4000	189	4000	189
12	$1\frac{1}{8}$	6	21.18	"	5000	236	5000	236
					Mean	165		165
6	$1\frac{1}{16}$	5	16.70	wedged	15000	898	29000	1736
7	$1\frac{1}{16}$	6	20.04	"	9000	449	20000	996
8	$1\frac{1}{16}$	4	13.36	"	4000	299	4000	299
10	$1\frac{1}{16}$	6	20.04	"	14000	699	25000	1243
11	$1\frac{1}{16}$	5	16.70	"	12000	718	24000	1436
					Mean	613		1142

TABLE I
Results for Bolts Set in Cement

No. of Exp.	Dimensions: Diam in inches	Dimensions: Length in inches	Dimensions: Surface of Contact in sq. in	Kind of Bolt	Stress: Starting: Total	Stress: Starting: lbs. per sq. in.	Stress: Ultimate: Total	Stress: Ultimate: lbs. per sq. in.
1	$1\frac{1}{8}$	6	21.18	plain	1000	48	1000	48
6	$1\frac{1}{16}$	6	20.64	"	1000	50	1000	50
					Mean	49		49
7	$\frac{3}{4}$	5	11.8	notched	3500	296	3500	296
8	$\frac{3}{4}$	5	11.8	"	1000	85	1000	85
					Mean	191		191
2	$1\frac{1}{8}$	11	38.83	threaded	15000	376	15000	376
3	$1\frac{1}{8}$	9	31.77	"	5000	158	5000	158
5	$1\frac{1}{8}$	6	21.18	"	5500	253	5500	253
9	1	6	18.84	"	2000	106	2000	106
10	$1\frac{1}{8}$	3	10.59	"	2000	190	2000	190
12	$1\frac{1}{8}$	6	21.18	"	5000	236	5000	236
14	$1\frac{1}{8}$	6	21.18	"	4000	190	4000	190
					Mean	213		213
4	$1\frac{1}{16}$	6	20.64	wedged	9000	450	25000	1750
11	$1\frac{1}{16}$	6	20.64	"	10000	485	10000	485
13	$1\frac{1}{16}$	6	20.64	"	15000	$\overset{7}{2}25$	24000	1160
					Mean	553		1132

CONCLUSIONS

The writer observed the following facts and derived the following conclusions during and from the experiments:

1. The cementing material has little to do with the power of anchor bolts.

2. The shape of the bolt is the main factor to give it strength.

3. The hole must be clean from dust and dry when the cementing material is poured in, or the bolt will loose the greater part of its holding strength.

4. The bolt must be directly in the line of the pull, or it will have but little resistance.

5. A slight blow with a hammer was sufficient to move or incline sideways all bolts set with only a wedge.

6. Cement is not a good material to use when the stress is likely to come on the bolt soon after it is put in place, because if the bolt is disturbed before the cement has set, the bolt will loose most if not all of its holding power.

7. To successfully set a bolt with

cement it is necessary to have a difference of at least $\frac{1}{2}$" between the diameters of the bolt and that of the hole. If the difference is less the cement must be thin enough to flow like cream and thus rapidly and entirely fill the space between the stone and the bolt in which case the holding power will not be the maximum.

8. The best form of bolt is a wedged rod surrounded by a cementing material.

9. If a wedged rod is used without any cementing material, it will split the stone if the latter is not exceedingly hard, or the bolt will pull out, after taking the shape shown in the following sketch.